NAVIGATION OF THE SPACE VLBI MISSION - HALCA*

Tung-Han You[†], Jordan Ellis[‡] and Neil Mottinger[†]

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

ABSTRACT

In February '97, the Japanese Space Agency ISAS launched the first space VLBI Space Observatory Program satellite (VSOP) using the newly developed M-V launch vehicle. The spacecraft renamed HALCA is an 800 kg spacecraft with an 8 meter diameter wire mesh antenna and radio astronomy receivers capable of observing at 1.6, 4.8 and 22 Ghz. The orbiting antenna in conjunction with a world wide network of ground radio telescopes will observe selected celestial radio sources simultaneously. After injection, three perigee raising maneuvers placed HALCA into a 560 by 21000 km orbit with a 6 hour period and a 31 degree inclination.

The VSOP program is part of an international collaborative effort which includes facilities in Japan, the U. S., Canada, Australia, and Europe, The U.S. role is to provide planning and operational support for the world wide network of radio telescopes. JPL is providing tracking and navigation support as well as co-observations using the 70 meter antennas. A new subnet of three dedicated 11 meter antennas was constructed at Goldstone, Canberra, and Madrid to track HALCA along with an NRAO antenna at Greenbank and ISAS antenna at Usuda. The tracking stations transfer a stable uplink reference frequency to HALCA, record the VLBI data which is downlinked in real time, and collect two-way Ku band doppler.

Precise navigation is vital for successful orbital operations as well as successful celestial radio source map construction. The reconstructed orbit accuracy requirement in the 22 Ghz frequency observing band is $80m$ in position and $4mm/s$ in velocity (1 sigma). Accuracy requirements for the predicted orbit are $175hz$ (3 sigma) in the received frequency at the spacecraft.

The major contributions of JPL Multi-Mission Navigation Group are to:

1. Provide predicted orbits to the DSN and Greenbank for uplink phase transfer
2. Provide reconstructed orbits to the U.S. Space VLBI project center for distribution to the NRAO VLBI correlator and international VLBI science community
3. Exchange orbit solutions and tracking data with ISAS Navigation

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† Member of Technical Staff

‡ Multi-Mission Navigation Group Supervisor

This paper describes the JPL orbit determination (OD) strategies, including spacecraft dynamic models and estimation methods, and the data interfaces used in meeting these accuracy requirements. Also presented are the techniques used to evaluate the reconstructed orbit accuracy and the results obtained using them. These techniques include comparing the overlapping segments of reconstructed trajectories as well as monitoring estimates of solar pressure and air drag coefficients obtained during the OD process.

Figure 1 demonstrates the navigation data interface of JPL Multi-Mission Navigation subsystem. Because of the complexity of the data flow, several Graphic User Interface (GUI) tools were developed to streamline the operations. Some of these are shown in Figure 2.

One of the limiting factors in meeting navigation accuracy requirements is the ability to accurately model the dynamic forces due to solar radiation pressure and atmospheric drag on the big 8 meter VSOP mesh antenna. As a result, different orbit determination strategies were developed to meet the prediction and reconstruction orbit accuracy requirements. While they both incorporate a seven day data arc and involve an epoch state filter, the techniques do vary:

1. For predicted orbit OD, constant drag and solar pressure coefficients are estimated and used in the trajectory propagation.
2. For reconstruction orbit OD, stochastic accelerations are estimated to obtain the best trajectory within the data span. Reconstructed orbit solutions use tracking data from DSN, Greenbank, and Japanese Usuda stations.

Figure 3 shows a typical one week span of radio metric data residuals based on a predicted orbit solution. Figure 4 shows relative trajectory differences in the overlapping portion of two reconstructed orbits. These two figures confirm our ability to meet the accuracy requirements for the predicted and reconstructed orbits.

VSOP is the first mission to extend VLBI techniques to incorporate an observing antenna in Earth orbit. In the collaborative efforts of the various participating international organizations, it has successfully produced images. There is great potential for applying the successful navigation techniques developed for VSOP to other missions, the Russian Radioastron mission being one of them.

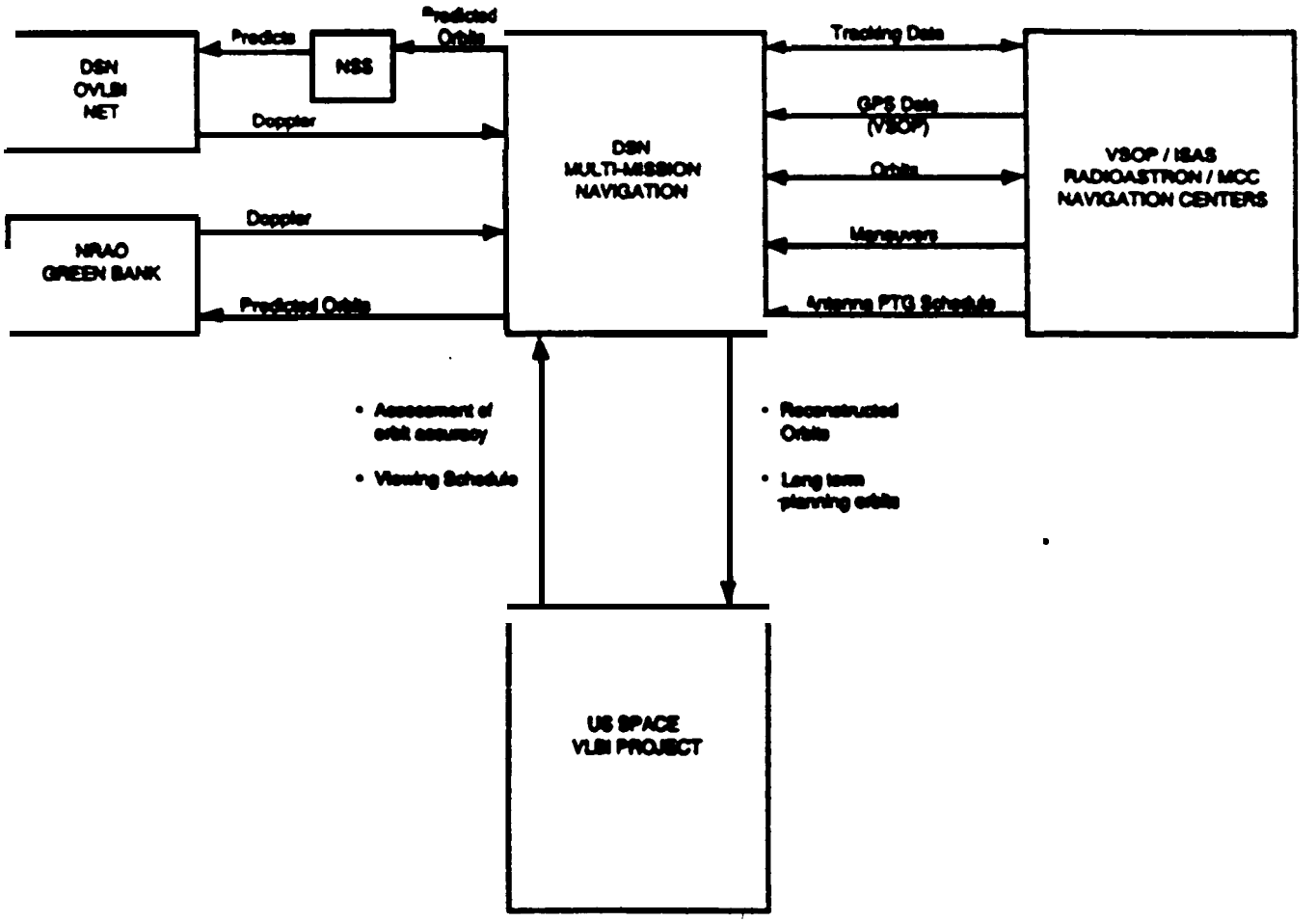
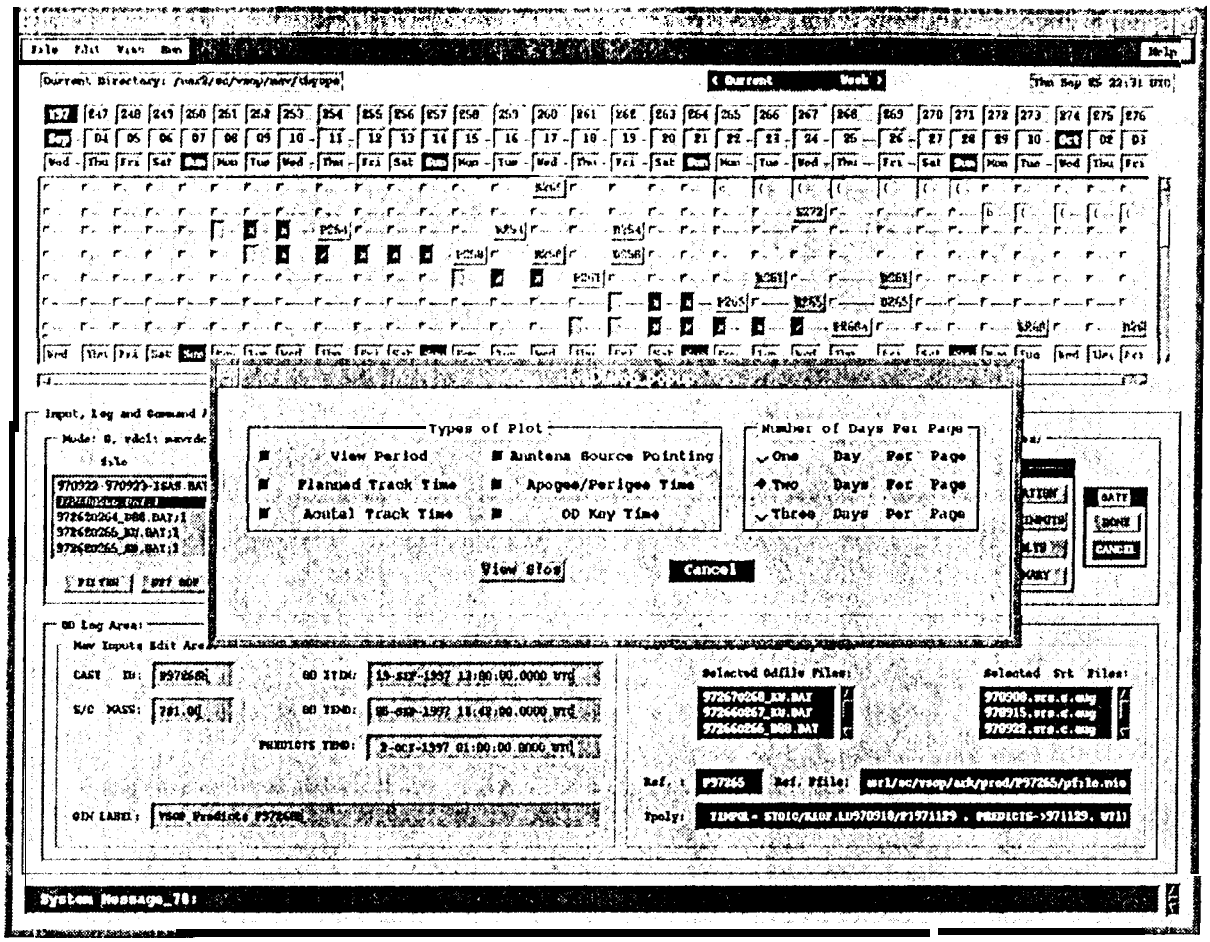
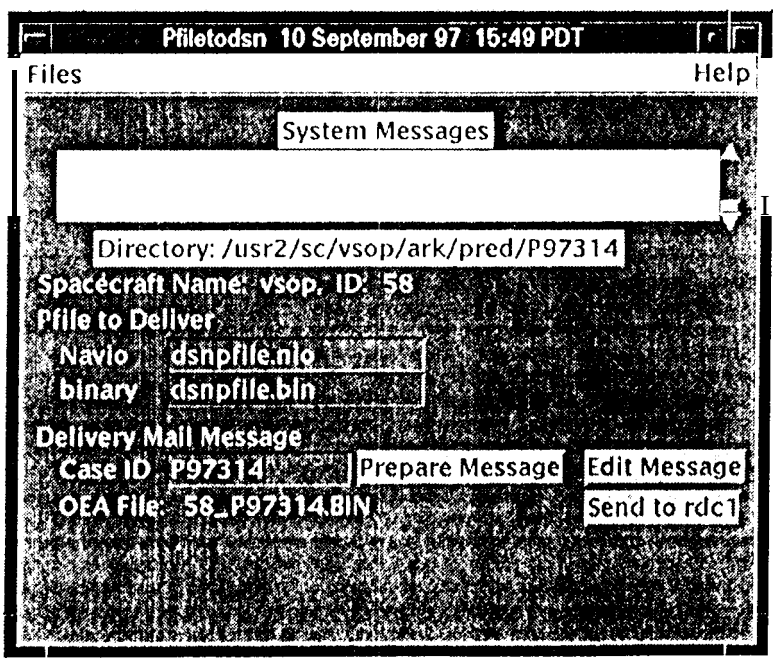


Figure 1 Navigation Data Flow

Figure 2: Samples of Navigation GUI Tools





~Uf93: **predicted residual(mrn/see) - P97090**

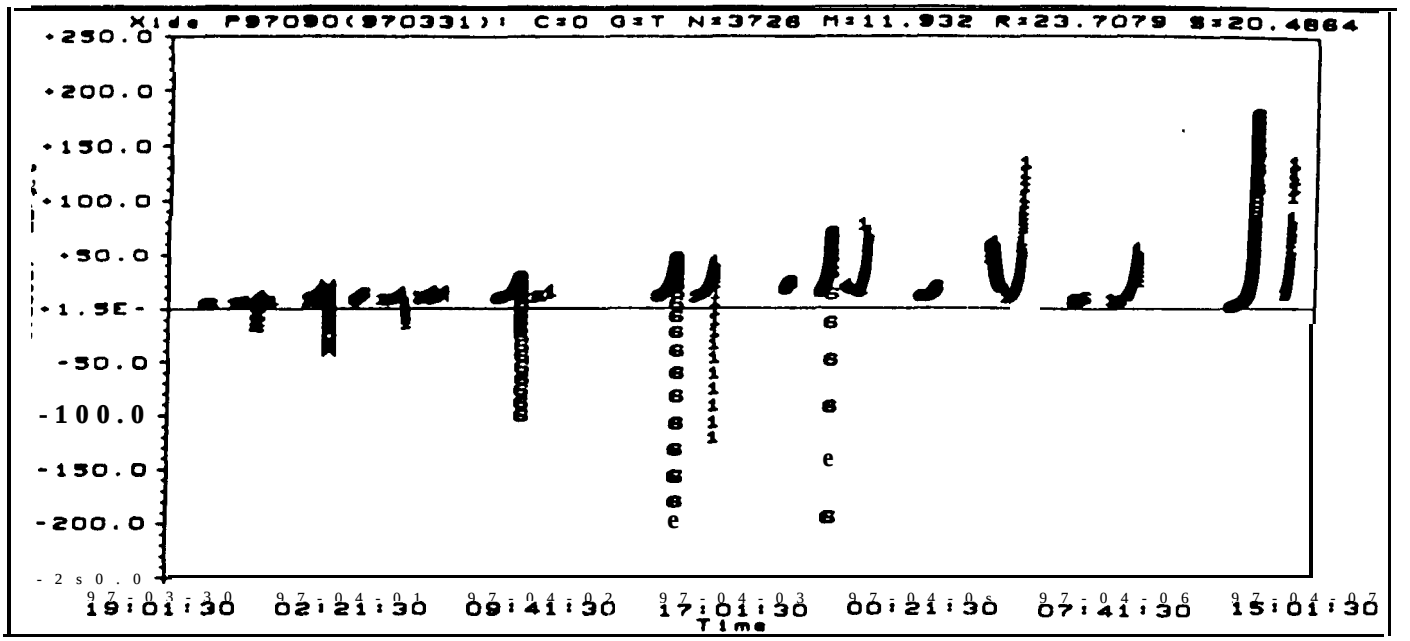
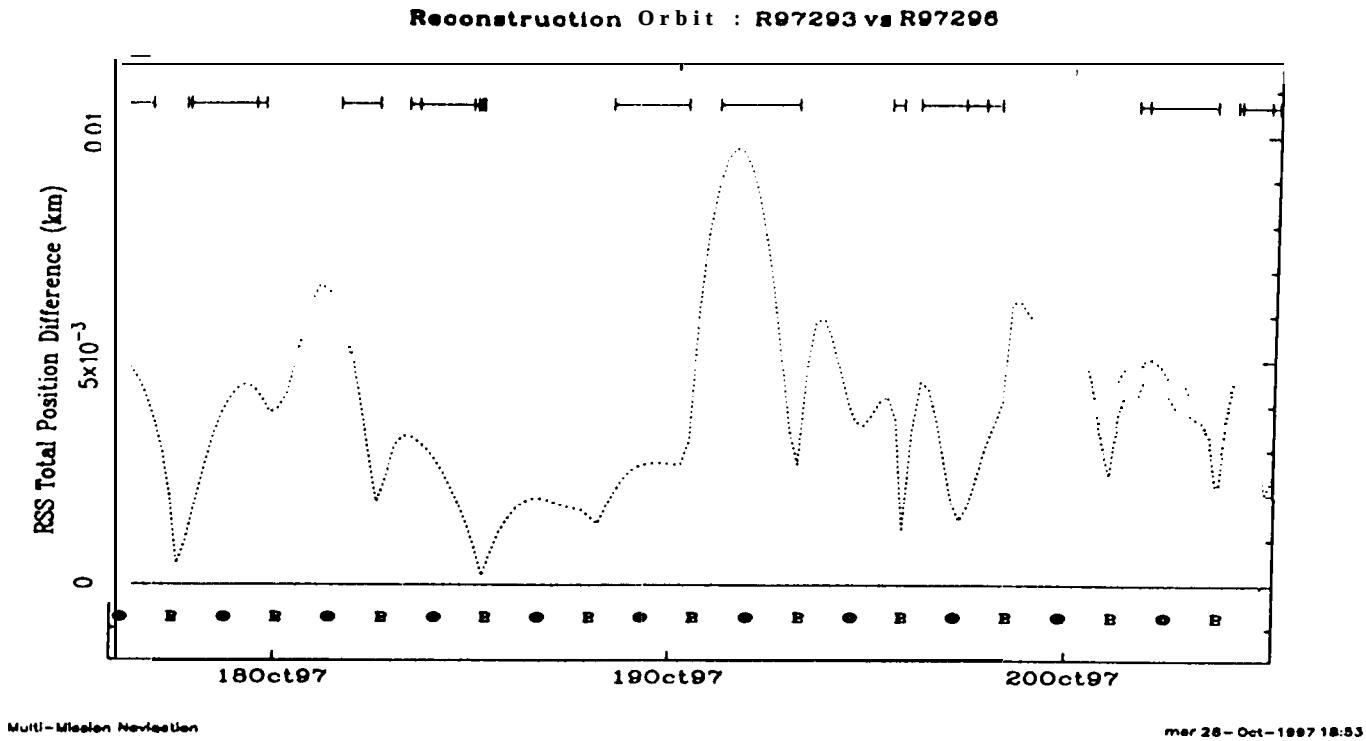
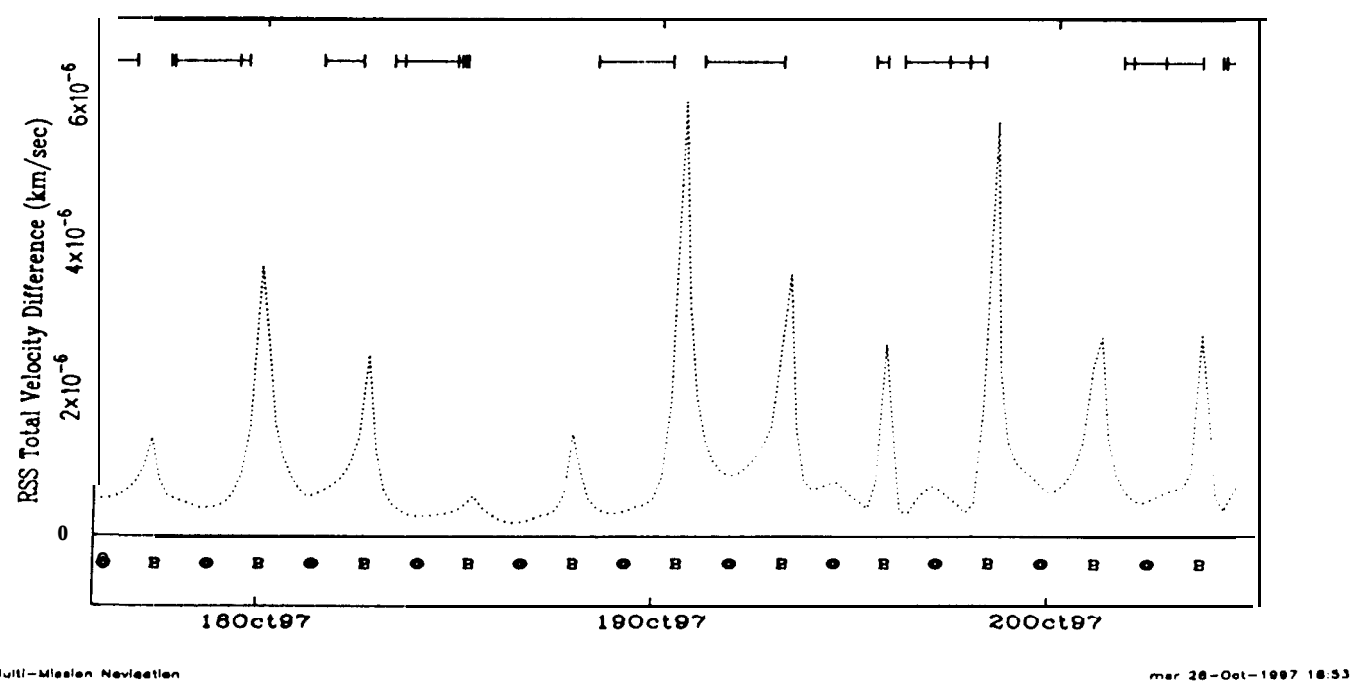


Figure 4: **Trajectory** Difference on View 1 **Frame**





293-296:.....
p(v) file#1:R97293/pv.nio
p(v) file#2:R97296/pv.nio